AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

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AHRI WHITE PAPER: "SMART" SYSTEMS

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Background

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Smart or Connected Equipment Ad Hoc Committee (Ad Hoc Committee) was formed in late 2011 following the U.S. Department of Energy's (DOE) August 5, 2011 request for information (RFI) regarding the treatment of smart appliances and equipment in future energy conservation standards and test procedures within DOE's appliance standards program, as well as in the test procedures for the ENERGY STAR Program.[1] DOE sought stakeholders' comments on smart appliance definitions as well as data from any field trials or market studies. One of the factors that led to the issuance of DOE's RFI was a joint petition that was submitted by the Association of Home Appliance Manufacturers (AHAM) and energy efficiency advocates to the U.S. Environmental Protection Agency (EPA) in January 2011.[2] The petition requested that EPA consider a five percent credit to the ENERGY STAR performance level for smart grid enabled appliances providing a demand response.

The National Institute of Standards and Technology (NIST) is currently responsible for bringing together regulators, manufacturers, consumers, and utilities to develop standards that deal with the smart grid. As outlined in the "The Energy Independence and Security Act of 2007" (Public Law 110-140, often referred to as "EISA"), NIST has been given "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems..." [EISA Section 1305]. In its second framework document for smart grid interoperability standards, NIST stated that DOE is the lead federal agency with responsibility for the smart grid. Under the American Recovery and Reinvestment Act (ARRA), DOE has sponsored cost-shared smart grid investment grants, demonstration projects, and other research and development efforts.[3] The NIST framework document also tasked the Federal Energy Regulatory Commission (FERC) with initiating rulemakings for adoption of smart grid standards as necessary to ensure functionality and interoperability when it determines that the standards identified in the NIST framework development efforts have sufficient consensus. Through its efforts with respect to standards coordination and harmonization, NIST intends to deliver the hundreds of communication protocols, standard interfaces, and other widely accepted and adopted technical specifications that comply with the NIST framework related to security, architecture and interoperability necessary to build an advanced, secure electric power grid with two-way communication and control capabilities. The framework document serves to guide the work of NIST's Smart Grid Interoperability Panel (SGIP) and support the safety, reliability, and security of the grid. Ultimately, the results of NIST's ongoing technical work may be considered by utilities, vendors, academia, regulators, system integrators and developers, and other smart grid stakeholders in future decision making.

Another consideration in forming the Ad Hoc Committee was the emergence of variable capacity air conditioning and heat pump systems, which have been or are being introduced by several AHRI member manufacturers. These variable capacity systems employ modulating compressors or variable speed compressors and offer the potential of substantially higher Seasonal Energy Efficiency Ratio (SEER) ratings and superior demand response performance compared to traditional fixed-speed, on-off systems. Since emerging variable capacity HVAC systems afford the capability to provide greater peak load reduction than traditional on-off systems (for the same reduction in cooling), the committee's initial focus has been on variable capacity HVAC systems. Lessons learned from this work could later be carried over to other applications, such as water heating or commercial refrigeration.

Many utilities, generating entities such as independent system operators (ISOs) and other third parties have shown interest in using water heaters to store renewable energy (such as wind) during transient load periods when the demand for electricity is low and the wind energy is high. In order to be able to react to such transient load periods, a water heater would need to be alerted via a utility or a third party signal. The ad hoc committee has agreed to address the demand response options available to water heaters.

However, the lack of standardized demand response performance characteristics and the lack of a common communications protocol from electric utilities complicate the benefits and slows the adoption of these technologies.

Purpose

The purpose of this white paper on "smart" systems is to communicate the Ad Hoc Committee's findings and position to all affected AHRI product sections for review and comment. The Ad Hoc Committee has taken all necessary steps to ensure that the AHRI white paper remains neutral with respect to the technology utilized by particular sections or members. The final white paper will be:

- Shared with regulatory agencies in order to communicate the industry's position on "smart" systems.
- Communicated to other industry trade associations that have similar objectives as AHRI.
- Used to facilitate joint research work with national laboratories and other research institutes.

- Used as background for developing AHRI standards, where appropriate, for demand response performance characteristics, etc.

Since its inception in late 2011, the Ad Hoc Committee has:

- Developed an Ad Hoc Committee scope and definition for “smart” systems.
- Participated in several meetings to learn and discuss how AHAM, National Electrical Manufacturers Association (NEMA), U.S. Green Building Council (USGBC), Pacific Northwest National Laboratory (PNNL), EPA, ClimateTalk Alliance, NIST, and Electric Power Research Institute (EPRI) are approaching “smart” system technologies.
- Reviewed potential objectives with respect to smart grid and demand response that may be common between our industry and industries represented by other trade associations.
- Developed a position and communicated a response to EPA's questions with respect to its draft specification on residential climate controls.
- Identified issues and positions that should be decided regarding demand response performance and communications characteristics in order to enable standardized, demand-response-ready products.

“Smart” Systems Definition

The Ad Hoc Committee recommends that “smart” categories of HVACR or water heating systems should at least be available as "demand response ready." Such products would have the capability to receive, interpret and act on a signal received from a utility or a third party; automatically adjust their operation according to preset minimum performance standards depending on both the signal’s contents and settings managed by the user or consumer; and communicate the product’s relevant status back to the utility. A demand-response-ready system would be sold with this capability, which could be built-in or added through an external device that easily connects to the equipment. The signals may include (but are not limited to) equipment or system startup delay, dynamic or peak load pricing, enable/disable functions, notifications for load-shedding to meet load control, energy storage (including pre-cool) mode, and resumption of normal operation. Any system operation settings/modes should be easy for an average, non-technical user or consumer to activate or implement. Additionally, a smart system may optionally have the capability to provide alerts and/or information to consumers via visual or audible means. While the system could be shipped with certain default settings (e.g. degrees of load control), it would not be activated until the owner enters into agreement with the utility or third party. Systems would also enable or permit consumers to override specific modes (e.g. override to maintain a set room temperature).

Ad Hoc Committee Scope

The Ad Hoc Committee feels that its work should focus on the management of electrical consumption of HVAC and water heating equipment, but that AHRI's Commercial Refrigerator Manufacturers Product Section should consider addressing additional issues related to the "smart/connected" characteristics of commercial refrigeration equipment separately, due to the broad array and complexity of products within its scope and the impact on food quality and safety. Of course, the findings of the Ad Hoc Committee will be shared with the Commercial Refrigerator Manufacturers Product Section.

Issues that Have Been Considered

Demand Response

HVAC and water heating systems contribute to utilities' loads on peak summer days. In addition to the load shedding benefits of standard on/off equipment commonly employed today, the Ad Hoc Committee recognizes that HVAC systems with capacity modulation or variable speed capabilities could present enhanced demand response capabilities in addition to enhanced energy efficiency performance. Utilities also have a growing interest in the demand response capabilities of electric water heaters.

The Ad Hoc Committee believes that:

1. It is not necessary to specify the technology within a smart system. While minimal demand response performance characteristics (i.e. kW reduction) should be sufficiently standardized to enable utility program managers to develop demand response programs, different manufacturers could develop different approaches and technologies to achieve the specified degree of load management.

2. The smart system should have the capability to receive a signal and confirm the receipt of the signal. Additionally, the smart system should have the capability to decide how to respond to the signal, based on standardized increments, consumer preference and consumer

agreements with utilities or other third party entities managing the demand response program.

3. Systems should provide consumers the ability to override a demand response signal. Upon such override, the system should communicate to the utility that the override has been implemented.

4. The effect of demand response programs on equipment reliability and system efficiency must be considered.

The Ad Hoc Committee views ancillary services as responses to momentary and transient load-side situations on the grid or brief intervals while generating facilities are brought on line. For this reason, ancillary services are sometimes considered "load-side spinning reserves." Utilities and aggregators are beginning to create markets for standardized "bundles" of ancillary services and the need for such services will likely increase as more variable renewable energy sources are deployed. The Ad Hoc Committee recommends that manufacturers consider the possibility of developing systems that could slow down (or even shut off) for short durations (for example, 10 minutes in a 24 hour period), subject to consumers' participation in utility or third party (aggregator) ancillary service programs.

The Ad Hoc Committee recognizes that any "demand-response ready" product must be pre-programed in ways that will enable it to respond to demand response or price response signals, should the home or building owner decide to participate in such utility programs. Since it would be impractical to program equipment for individual programs from hundreds of individual utilities, a degree of standardization will be required so that the utility program could "activate" or signal those performance characteristics appropriate for its load situation and climate zone.

The concept of thermal storage is beginning to be considered in the discussions of the smart grid. This very flexible capability exists in water heaters and in building envelopes. The committee recognizes that electric water heaters can be utilized as energy storage devices to accept brief or sustained periods of excess energy from renewable resources, such as wind, solar or hydroelectric sources. DOE is beginning to explore methods of standardizing measurements of energy storage in its work with PNNL, titled "*Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems.*" Some AHRI members are already involved in this activity.

In December 2012, EPRI developed a preliminary draft on load management for variable capacity residential systems. Members of the Ad Hoc Committee had an opportunity to review and comment on this draft and interact with EPRI staff on the following demand response performance parameters:

1. The degree of power reduction that can be achieved for given intervals in heating or cooling output of variable capacity systems.

2. The practical increments of an equipment's output reduction. For example, could a given air conditioner be programmed to reduce cooling output in 15%, 20%, 25% or 30% stages? If such levels were standardized across manufacturers, the utility program developer could then tailor a demand response program to achieve the utility's own desired results, or to match different incentive or rebate levels for specific segments of customers, while avoiding complex unique requirements.

3. Should the equipment's output reduction be measured from the rated output of the system (e.g., 36,000 Btu/h for a three ton unit) or from the actual operating point at the onset of the demand response event?

4. Could the system be programmed to precool the building or home prior to a demand response event, upon receiving a specific signal from the utility, in order to mitigate the comfort impact or to permit further power reduction during a demand response event?

5. Should or could the system be programed to respond to the utility, thereby confirming the degree of power reduction achieved?

6. How should the system perform at the conclusion of the demand response event? Should it immediately resume normal operation, or should output be gradually increased to minimize the rebound effect on the utility grid?

EPRI was asked to evaluate two other related considerations:

7. Confirm and quantify the increased heating capacity of variable speed heat pumps in colder climates, compared to fixed speed heat pumps.

8. Evaluate whether a ½ ton increase in nominal cooling capacity for a given building would provide the benefit of further energy savings because of the higher energy efficiency while operating at a lower percentage of full load output, and/or whether such a ½ ton increase in nominal capacity could exacerbate utility peak load situations, and to what extent.

Once EPRI's evaluations are complete, the recommended performance for each demand response parameter could be reviewed with several prominent electric utilities for confirmation or refinement. Members of the Ad Hoc Committee would then assess the impact of variable capacity systems and the possible performance standardizations that could be agreed upon by the industry.

Following this confirmation, the recommended performance characteristic would be provided to the AHRI Unitary Small and Large Equipment Product Sections to consider for inclusion in an AHRI Standard.

This level of detailed work has not yet occurred with water heaters. AHRI's water heater member manufacturers are beginning to discuss the work that needs to be performed with respect to water heaters, including further discussions with other stakeholders such as EPRI on this issue.

Note: While EPRI's research specifically relates to variable capacity heating and cooling equipment, we expect that certain results could benefit other residential systems as well. For example, heat pump water heaters currently being introduced could provide similar demand response benefits if equipped with variable capacity heat pump systems. Findings in EPRI's current research could possibly lead to similar research in water heating systems.

<u>System Controls</u>

Traditional 24v thermostats have been used for decades as on-off control devices that simply signal a furnace, air conditioner, or heat pump to turn on or off, or to switch between stages based on temperature set-points. Variable capacity HVAC systems do not simply turn on and off, but rather adjust their output with the goal of matching the load. By operating at a capacity closer to the load, the variable capacity system is able to provide significantly higher energy efficiency. In many of these systems, the thermostat is replaced by a user interface and temperature/humidity sensors linked to controls in the equipment.

For the traditional on-off single stage systems, temperature setback control can be a viable strategy for demand response and energy efficiency programs. However, in variable capacity systems, temperature setback is not an optimal strategy and should not be specified by regulatory authorities. Equipment manufacturers must have the flexibility to optimize the performance of their products in terms of energy efficiency, demand response performance and control strategy.

The Ad Hoc Committee believes that communicating equipment can provide ancillary services and demand response capabilities to address utility signals or grid events.

As stated earlier, water heaters are becoming a very important part of the smart grid discussion and are helping to facilitate the use of renewable generating devices (i.e. hydro, wind and solar). Thermal storage is a great advantage to the grid. Smart controls on water heaters will serve to maximize utilities' utilization of these very flexible load devices.

ENERGY STAR – Draft Program Requirements for Residential Climate Controls

The Ad Hoc Committee has reviewed the first version of the EPA's specification for climate controls.[4] The specification defines a climate control to be a "device," such as a legacy thermostat. It appears to imply that a single, stand-alone product is used for temperature monitoring and control of a traditional on-off HVAC system and that communications are utilized simply to provide a remote interface to this device. This perspective is accurate for most traditional legacy-thermostat controlled HVAC systems today, whether or not the device has communicating capabilities. However, it is important to recognize that this paradigm of a stand-alone "climate control" product or device is not necessarily appropriate for the more energy efficient variable capacity HVAC systems that are now emerging.

AHRI member companies are independently continuing to research and develop advanced HVAC technologies and control techniques that recognize and leverage the benefits of a coordinated HVAC system. Distributed and remote sensing, and variable capacity operation are some of the elements of these optimized systems. The ENERGY STAR approach to define a climate control as a singular device should be reconsidered as it may not be compatible with the future direction for optimally designed, energy efficient HVAC systems. The Ad Hoc Committee recommends that EPA revise its requirements to recognize the value of an integrated system approach. EPA also should recognize that temperature and other sensing needs may not be integral to only a singular controlling device.

The Ad Hoc Committee believes that while a standard method of interface between a residential HVAC system and a utility is optimal, it should not be assumed that the point of connection is within what we would today understand to be a thermostat or smart system controller. An advanced HVAC system may be designed to act on a demand response, price signal response, or ancillary service request without the utilization of a traditional thermostat or a smart system controller. Additionally, although specifications should be considered for "demand response ready" thermostats or "smart controllers" for traditional fixed-speed, on-off HVAC systems, the same specifications may not apply to variable capacity HVAC systems, unless those specifications are written with enough latitude to anticipate new technology likely to be implemented in advanced HVAC systems.

Lastly, the Ad Hoc Committee believes that a smart system should encourage interoperability between equipment and utilities so that all manufacturers' systems can be utilized on all utilities' grids. There should be a mechanism to interface with the system, but the fact that utilities are not in agreement with protocols on their end complicates the issue. The Ad Hoc Committee is developing recommendations for communications protocol standards for equipment represented by AHRI.

Smart Grid Communication Standards

Although the Ad Hoc Committee decided not to pursue a standard for common internal communication protocols within the smart system's components, it believes that some degree of standardization is required for external communication of load control and load reduction information between equipment and a utility or other demand response, price response or ancillary services program provider.

The message set of a communication method between HVAC and water heating equipment and a utility should be able to handle the following interactions in a standardized manner:

1) Reporting the demand response or energy storage capabilities that are available within the system. The system should have the capabilities to respond to a finite number of demand response or energy storage classes to make it easier for utilities to design programs that will be consistent with equipment capability. Utilities can design programs with eligibility criteria based on such classes and verify equipment eligibility via communication with the equipment.

2) Responding to a request by the utility for an action from the smart system. Since the smart system has shared its capability with the utility in the form of a standardized demand response or energy storage class, the utility will only request actions that are possible within the system. Also, the actions requested can be in line with whatever agreement the utility has in place with the customer.

3) Since it is critical that a consumer have override capabilities, there needs to be a way for the equipment to report data that can be used by the utility to verify a smart system's operation pursuant to the agreement that a consumer has with the utility.

4) Messaging from the utility to be used for announcements to the consumer of pending actions, requests for voluntary action, notification of current actions, etc.

5) Messaging from the utility to be used to communicate dynamic pricing information. As an alternative to the use of a demand response method involving a utility intervening in normal operation, the equipment can be designed to respond automatically or manually to changes in pricing if that

information is available to the equipment. This facilitates a market-based demand response method and allows individual users to make decisions balancing the values of comfort and cost as they see fit.

There are benefits to standardized communication between smart systems and utilities that leverage a low cost infrastructure and can be readily implemented. We believe that communication standards such as Open Automated Demand Response (OpenADR) 2.0 and Smart Energy Profile (SEP) 2 include elements that are helpful in standardizing the communication between smart systems and utilities.

In December 2012, AHRI surveyed members of the AHRI Unitary Small Equipment, Ductless Equipment, Furnace and Water Heater Product Sections regarding the appropriateness of the SEP 2 and OpenADR 2.0 profiles. After examining the survey results and extensively reviewing the standards, the Ad Hoc Committee concluded that SEP 2 and OpenADR 2.0 are very capable smart grid communication standards. Manufacturers also concluded that it would be practical to design and produce equipment capable of communicating with either communication protocol, depending on the one chosen by the local utility.

The Ad Hoc Committee views SEP 2 as a standard that is appropriate for residential and light commercial systems that communicate with the smart grid. SEP 2 is believed to be technology-independent and useful for many smart grid applications.[5] A significant improvement of SEP 2 over the previous version of the standard is that it is now loosely coupled, thereby allowing it to interoperate across other network layers, platforms, and media. However, the intent of SEP 2 is not to replace ZigBee Smart Energy version 1 standard. Rather, SEP 2 is intended to offer utilities and energy service providers with additional choices. Some additional features of SEP 2 include prepay services, user information and messaging, load control, demand response, and common information and application profile interfaces.

The OpenADR standard was developed by Lawrence Berkeley National Laboratory and the California Energy Commission and is currently supported by the OpenADR Alliance. According to the Alliance, the standard is an open global standard that enables electricity providers and system operators to automatically communicate demand response signals with each other and with customers using a common language over any existing IP-based communications network.[6] OpenADR standardizes demand response price and reliability messages, thereby automating and simplifying customer demand response participation, and improving demand response event results. The Ad Hoc Committee views the Open ADR 2.0 profile to also be appropriate for applied commercial and industrial buildings. The standard is system focused and scalable, and likely is interfaced to a comprehensive commercial building automation/energy management system. The standard would work with various building automation protocol standards (e.g., BACnet). Some other key benefits of the standard identified by the OpenADR Alliance include:

- Rapid delivery of price and event information through a secure network
- Improvement in the predictability of demand response resources before/during an event
- Increased incentives available from utilities to implement automatic demand response-enabled control systems
- Support for ‘fast demand response’ that will facilitate the integration of an increasing amount of renewable energy sources and the use of demand response for ancillary services
- Reduced cost of deploying automatic demand response programs and technologies as OpenADR functionality is designed directly into third party products

In December 2012, the OpenADR Alliance announced that California investor-owned utilities plan to require the OpenADR 2.0 standard for new customers in their Demand Response Enabling Technology programs in 2013. Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E) and Southern California Edison (SCE) are expected to add OpenADR 2.0 certified products to support locational dispatch of emergency and price demand response, resources that are intended to better manage peak demand without the need for expensive new power plants.

Review of Other Related Industry Standards and Programs

NEMA Standard DC-3, Annex A – *Energy Efficiency Requirements for Programmable Thermostats*

In 2010, NEMA launched the Energy Aware certification and labeling program for programmable thermostats.[7] The Ad Hoc Committee believes that the standard associated with the labeling program effectively addresses the elimination of the ENERGY STAR labeling program and establishes an alternative for consumers regarding energy efficient purchases.

BSR/ASHRAE/NEMA Standard 201P – *Facility Smart Grid Information Model*

This standard is communication protocol independent. NIST anticipates that it will be used by several standards developing organizations and others to make protocol specific implementations. The standard is an information model standard designed to enable appliances and control systems in homes, buildings, and industrial facilities to manage electrical loads and generation sources in response to communication with a smart electrical grid. It also provides for communication of information about those electrical loads to utility and other electrical service providers.

The model within the standard defines a comprehensive set of data objects and actions that support a wide range of energy management applications and electrical service provider interactions including on-site generation, demand response, electrical storage, peak demand management, forward power usage estimation, load shedding capability estimation, end load monitoring (sub metering), power quality of service monitoring, utilization of historical energy consumption data, and direct load control.

The advisory public review draft of ASHRAE Standard 201P was released in July 2012.[8] The Ad Hoc Committee reviewed this draft and believes that Sections 4.2.5 and 5.3 of this standard seem to be most relevant for AHRI members. Although the standard mentions that energy management systems would be used to monitor and control the energy consumption of HVAC equipment, the standard does not specify the detailed steps that are necessary to extend the information model toward practical applications.

Ad Hoc Committee Interaction with Laboratories

Pacific Northwest National Laboratory (PNNL)

In May 2012, PNNL identified the following opportunities:

- Peak load shifting – setpoint adjustment or pre-cooling/pre-heating in advance of peak load period for unitary systems, setpoint adjustment through the addition of a mixing valve or transactive thermostats for electric water heaters, and slowing down and taking advantage of mass in pipelines for chillers, pumps, fans, and cooling towers.

- Mitigating wholesale price peaks by shifting load to lower cost periods – this is basically the same as peak load response. Many price spikes are caused by disruptions to normal grid operations, or missed forecasts for renewables. Although a significant value is obtained from a short term response (lasting approximately from 15-30 minutes), full value can only be obtained through continuous response throughout the year. However, continuous response needs to be highly automated and not interfere with higher value peak load response.

- Providing spinning reserve – equipment having the capability to utilize the extra generating capacity of power plants that are made available for short durations. The cost of electricity during such periods is higher than the cost of wholesale electricity. Demand response ready systems can be used to mitigate the extra capacity costs associated with operating spinning reserves.

- Providing regulation services – supplying regulation services with demand response could help manage renewable power. Responsive loads could supply regulation services by turning a sub-process on/off for a few minutes, slowing a process and returning it to normal, or increasing/decreasing a setpoint. However, short-cycle protection is imperative in such cases.

Electric Power Research Institute (EPRI)

The Ad Hoc Committee has also interacted with EPRI staff and recommends that EPRI jointly participate with the Air-Conditioning, Heating, Refrigeration Technology Institute, Inc. (AHRTI) on research projects that are of mutual interest to the two organizations.

In July 2012, EPRI reported to the Ad Hoc Committee that EPRI's ongoing research is evaluating energy management systems, thermal energy storage systems, chillers, and other commercial HVAC equipment, data centers and refrigeration systems in commercial buildings. EPRI is also evaluating the response time and ancillary services capability for grid interactive water heaters.

In January 2013, EPRI began its evaluation of load management for variable capacity residential HVAC systems. While this research work specifically relates to variable capacity heating and cooling equipment, EPRI expects that certain results could benefit the understanding of other residential systems as well, including water heaters.

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